
Webinars
Using Well Heterogeneity as an Advantage to Designing Stage Specific Diverter Strategies
Kevin Wutherich – Chief Technology Officer
SPE International
DRILL 2 FRAC®
World Oil Awards
2018 WINNER


Webinars
SPE Webinars are Sponsored by:
SPE
SPE Foundation
SPE International

Speaker

Webinars

Kevin Wutherich

SPE International

3

Outline

Webinars

Introduction
Diversion Effectiveness
Diversion Dynamics
Design Considerations
Wellbore Effects
Fully Engineered Diversion
Case Study
Conclusions

SPE International

Introduction

Introduction

- What are diverters?
  - A chemical agent or mechanical device used in injection treatments to ensure a uniform distribution of treatment fluid across the treatment interval.
  - Injected fluids tend to follow the path of least resistance, possibly resulting in the least permeable areas receiving inadequate treatment.
  - To be effective, the diversion effect should be temporary to enable the full productivity of the well to be restored when the treatment is complete.
  - There are two main categories of diversion: chemical diversion and mechanical diversion.
    - Chemical diverters function by creating a temporary blocking effect that is safely cleaned up following the treatment, enabling enhanced productivity throughout the treated interval.
    - Mechanical diverters act as physical barriers to ensure even treatment.

SLB Oilfied Glossary

Introduction

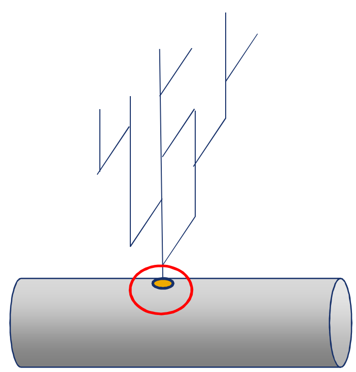
- In hydraulic fracturing, diverter is primarily used for two purposes:
  - Increase cluster efficiency: By adding diverters to a standard design, fluid will be diverted from clusters taking the most fluid, to those taking little to no fluid.
  - Increase stage length: More clusters are treated per stage than a standard design through the use of diverter.

Types of Diverter

Perforation Sealers

– Act by blocking the perforation at the casing

- Pros
  – Easy to control quantity (1 sealer per perforation)
  – Old,proven Technology
  – Can't damage formation
- Cons
  – Can be effected by eroded perforations
  – Hard to determine how many perforations are open

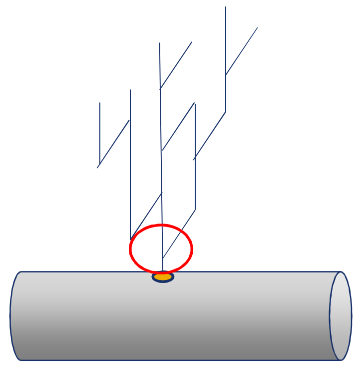


Types of Diverter

Near wellbore diverter

- Typically a particulate material that clogs the perforations/fractures within 0-5 feet of wellbore

- Pros
  - Easy to pump operationally
  - Cost effective
  - Not dependent on perforation geometry
  - Can create very effective barrier to flow
- Cons
  - Difficult to determine optimal amount to pump

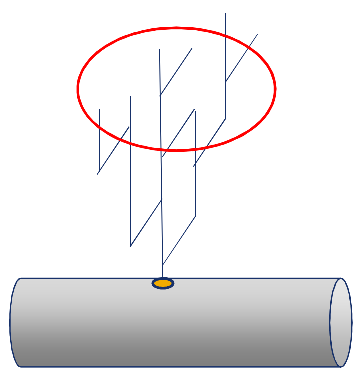


Types of Diverter

Far-Field wellbore diverter

- Typically a particulate material that arrests fracture growth away from the wellbore

- Pros
  - Can be used to prevent height growth or reduce probability of frac hits
- Cons
  - Not as effective as other methods at increasing pressure to open new perforation clusters
  - Difficult to control where or when diversion will happen



Poll

Webinars

- What type of Diverter have you tried/considered
  - Perforation Sealers
  - Near-Wellbore
  - Far-Field
  - None

If possible, use multiple choice poll

SPE International

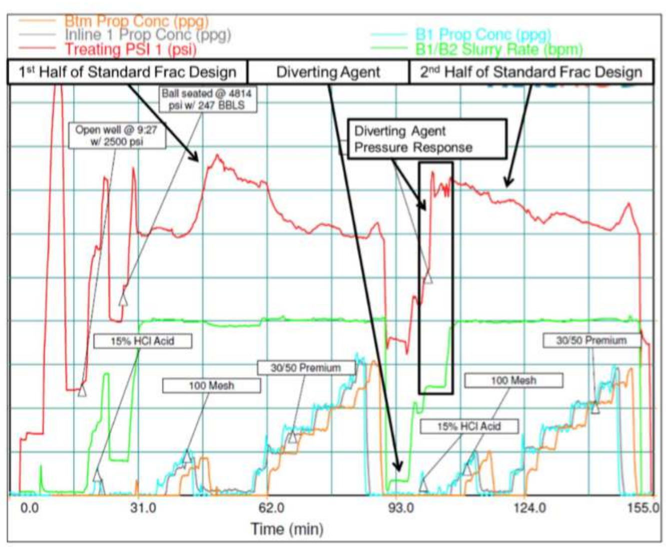
Applying Diverter

Webinars

Typically diverters are applied in a one size fits all manner.

Example:

- pump first 50% of job
- drop diverter
- pump remaining 50% of job



SPE International

Poll

- How do you apply diverters
  - Every stage is the same
  - Adjust each stage based on real time measurements
  - Adjust each stage based on previous stage
  - Adjust each stage based on

(only answer if you've used diverter)

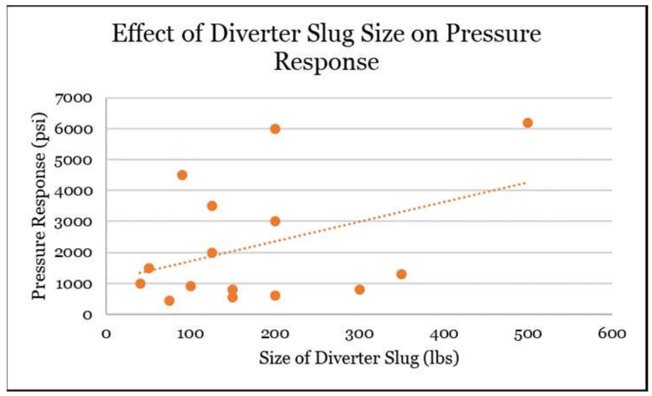
Diversion Effectiveness

Diverter Response

Webinars

- Use of diverter typically results in inconsistent pressure responses

- Variation in rock properties results in varied diversion response



From Southwest Petroleum short course (2018): Using Engineered Diversion Strategies to effectively stimulate new rock

SPE International

Poll

Webinars

- When you use diverter, how would you describe the pressure response from stage-to-stage (drop-to-drop)
  – Very consistent (+/- 100 psi response)
  – Consistent (+/- 500 psi response)
  – In-consistent (+/- 1000 psi response)
  – Unpredictable

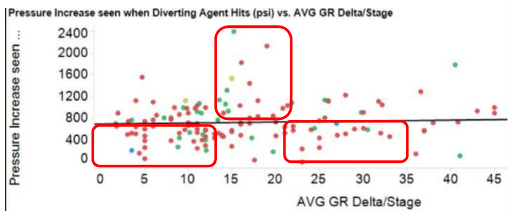
(only answer if you've used diverter)

SPE International

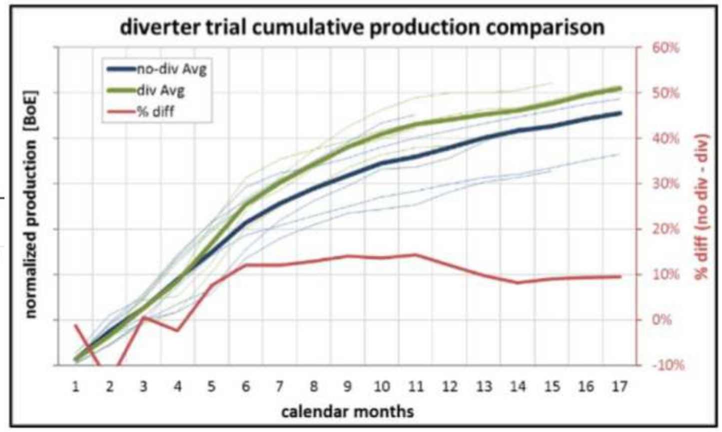
Diverter Effectiveness – SPE 187218

Webinars

Wolfcamp Shale Example



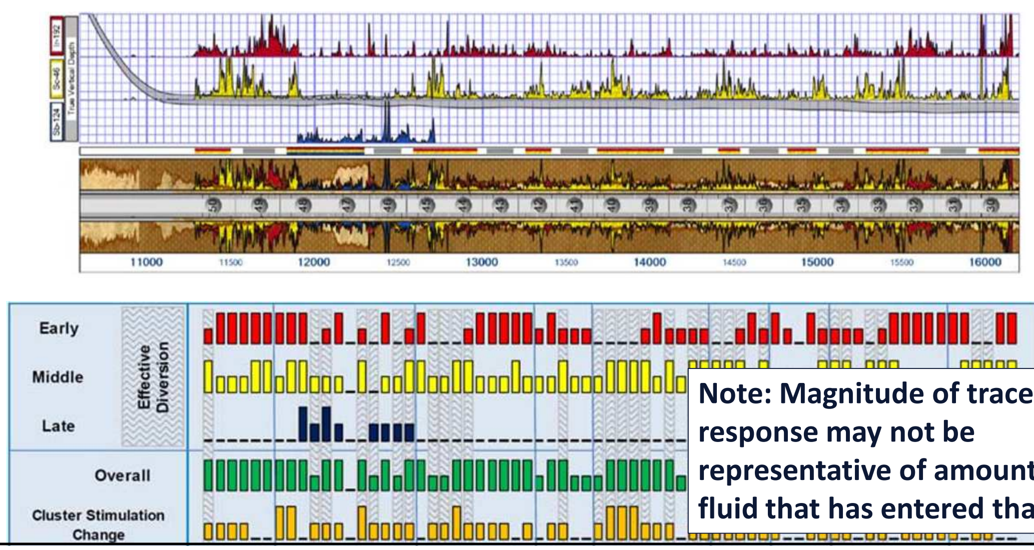
Pad	% of Stages W/Diverter Pressure Increase > 500
4	81%
2	68%
2	71%
3	68%
3	87%
Average	75%



75% Effective = 10% improved production

Diverter Effectiveness – SPE 189900

Webinars



Note: Magnitude of tracer response may not be representative of amount of fluid that has entered that area

Diverter Effectiveness – SPE 189900

Webinars

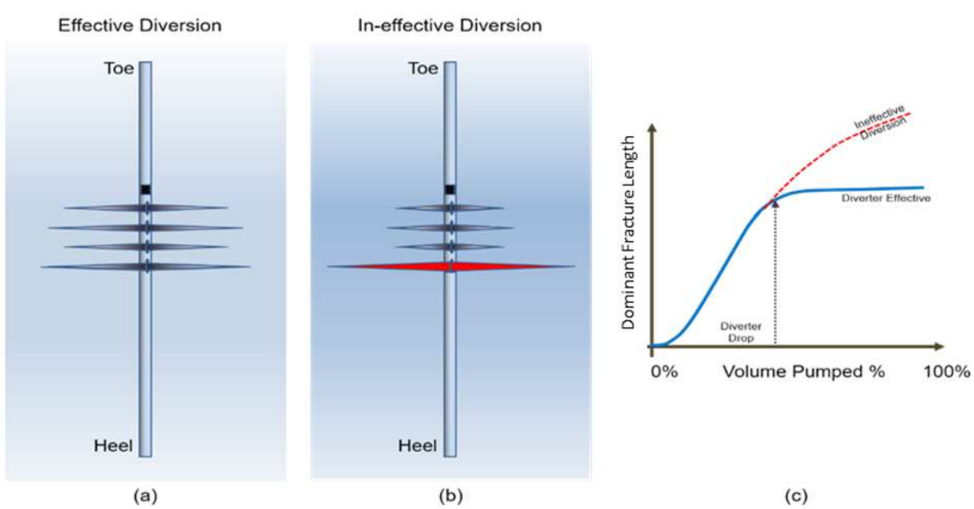
PLA	Clusters	Perf Efficiency (%)	Diversion?	Effective Diversion?
Stimulated Clusters	1069			
Total Clusters	1220	87.6%	88.7%	59.3%
Pods				
Stimulated Clusters	448.5			
Total Clusters	504	89.0%	97.0%	70.1%

Diversion is defined as an increase in pressure when diverter hits perforation
Effective Diversion is defined as tracer appearing in new areas after diversion

SPE International

Diverter Effectiveness – URTeC 2902114

Webinars



Diverter Effectiveness – URTeC 2902114

DiverterSCAN ™ Results	Surface Pressure Treatment - Max Treating Pressure comparison	
	True Positive 12	False Negative 3
	False Positive 3	True Negative 4

DiverterSCAN ™ Results	Surface Pressure Treatment - Mean Pressure comparison	
	True Positive 14	False Negative 2
	False Positive 5	True Negative 1

DiverterSCAN ™ Results	Surface Pressure Treatment - Diverter Pressure Spike	
	True Positive 10	False Negative 0
	False Positive 9	True Negative 3

DiverterSCAN ™ Results	Surface Pressure Treatment - Ratio of Treating Pressures	
	True Positive 5	False Negative 6
	False Positive 9	True Negative 2

Pressure Response
= 76% effective

Poroelastic Response
= 59% effective

Diverter Effectiveness - Summary

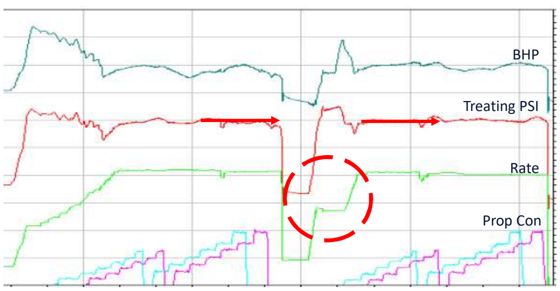
Paper	Formation	Diverter Type	Success via Pressure Response	Success via diagnostic
SPE 187218	Wolfcamp	PLA	75%	N/A
SPE 189900	Multiple	PLA	89%	59%
SPE 189900	Multiple	PODs	97%	70%
URTeC 2902114	STACK	PODs	76%	59%

In general, pressure response alone is not an indication of successful diversion

Criteria for Effective Diversion

Ineffective Diversion

- Increase in pressure when diverter hits
- Pressure quickly returns to same level as it was prior to diversion



Effective Diversion

- Increase in pressure when diverter hits
- Slope of pressure changes after pressure response

Poll

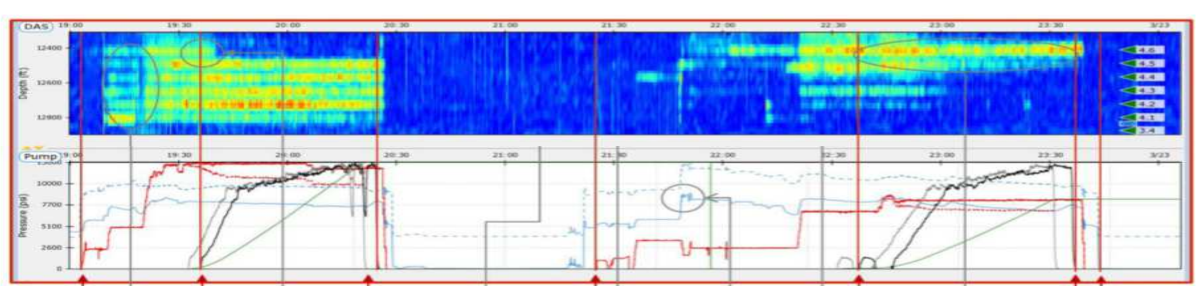
- How effective have diverters been in improving production?
  - Significant Increase
  - Marginal Increase
  - Inconclusive/Negligable effect
  - Production Decrease

(only answer if you've used diverter)

Diversion Dynamics

Sample Diversion

- In this example, we can see that the operator was initially pumping into 5 of 6 clusters.
- Diverter was dropped after 50% of job after which only 1-2 clusters taking fluid

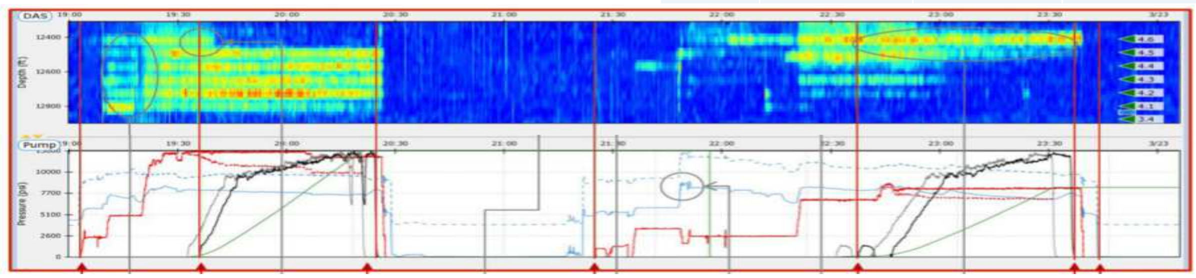


SPE 173348

Sample Diversion

Assuming best case scenario of equal distribution, clear that clusters 5 and 6 are over stimulated.

	Before Diverter	After Diverter	% of Proppant
Cluster 1	20%	0%	10%
Cluster 2	20%	0%	10%
Cluster 3	20%	0%	10%
Cluster 4	20%	0%	10%
Cluster 5	20%	50%	35%
Cluster 6	0%	50%	25%

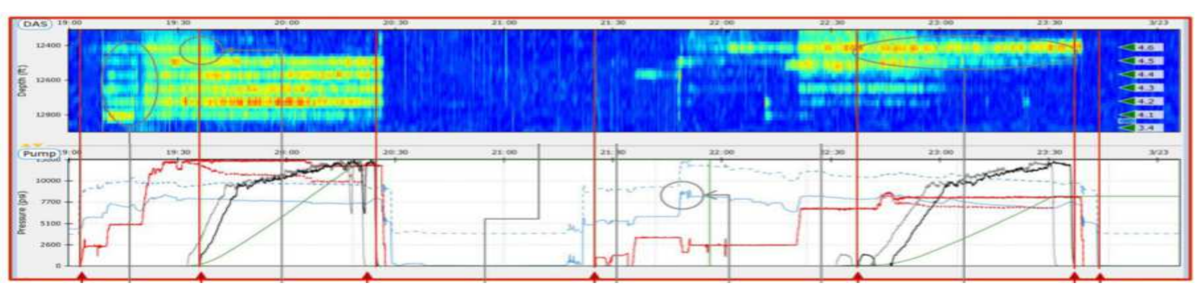


SPE 173348

Sample Diversion

If we could predict which clusters would take fluid initially, what would we do different?

What if we could control when each cluster takes fluid?

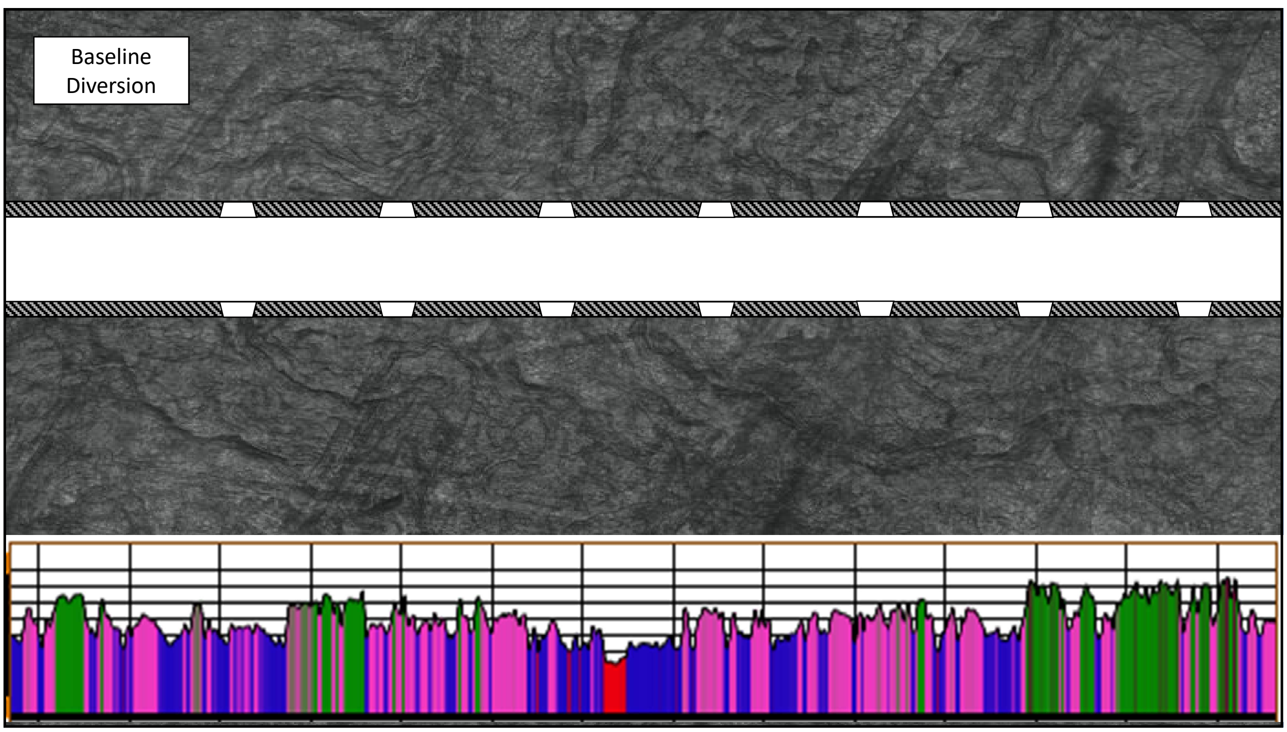


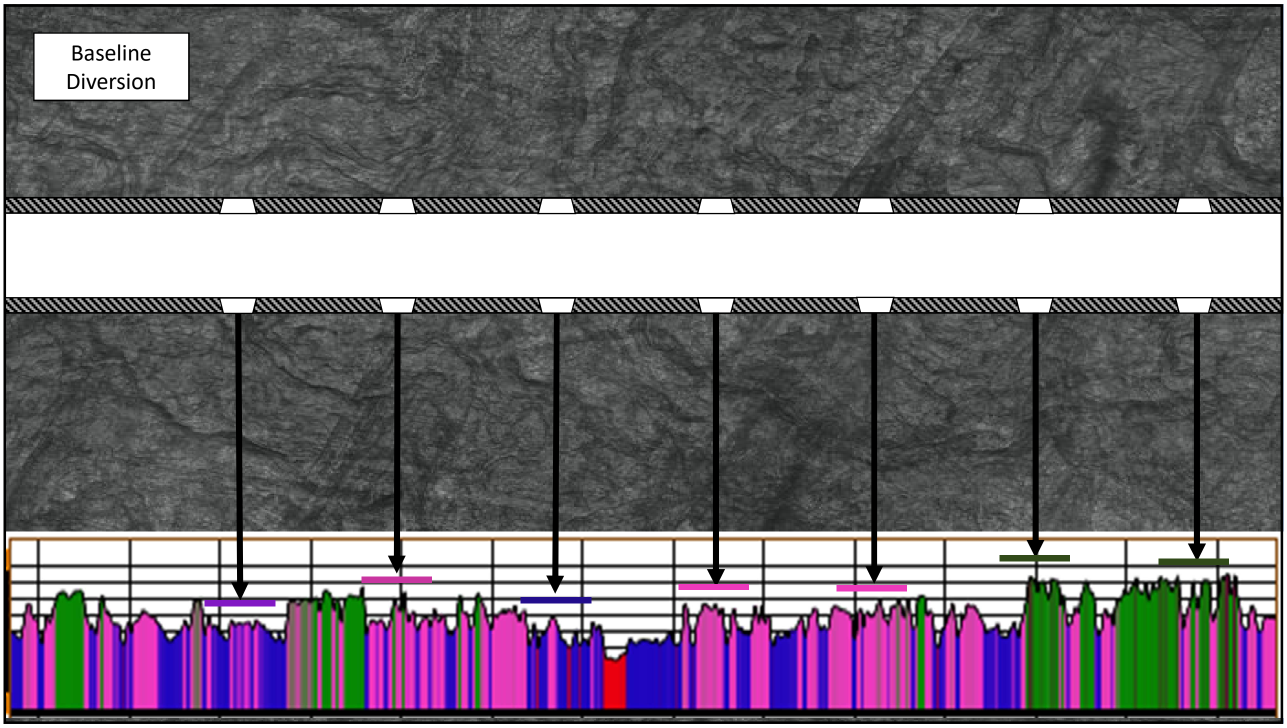
SPE 173348

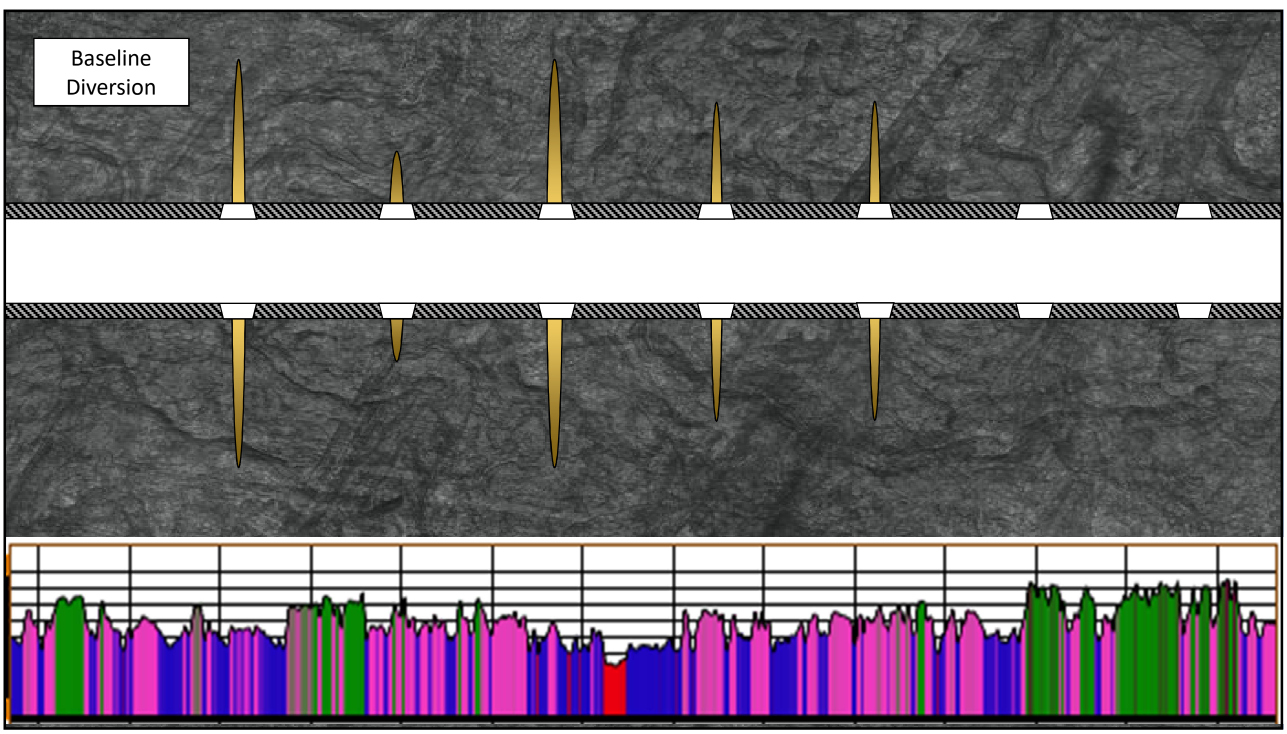
What is happening downhole?

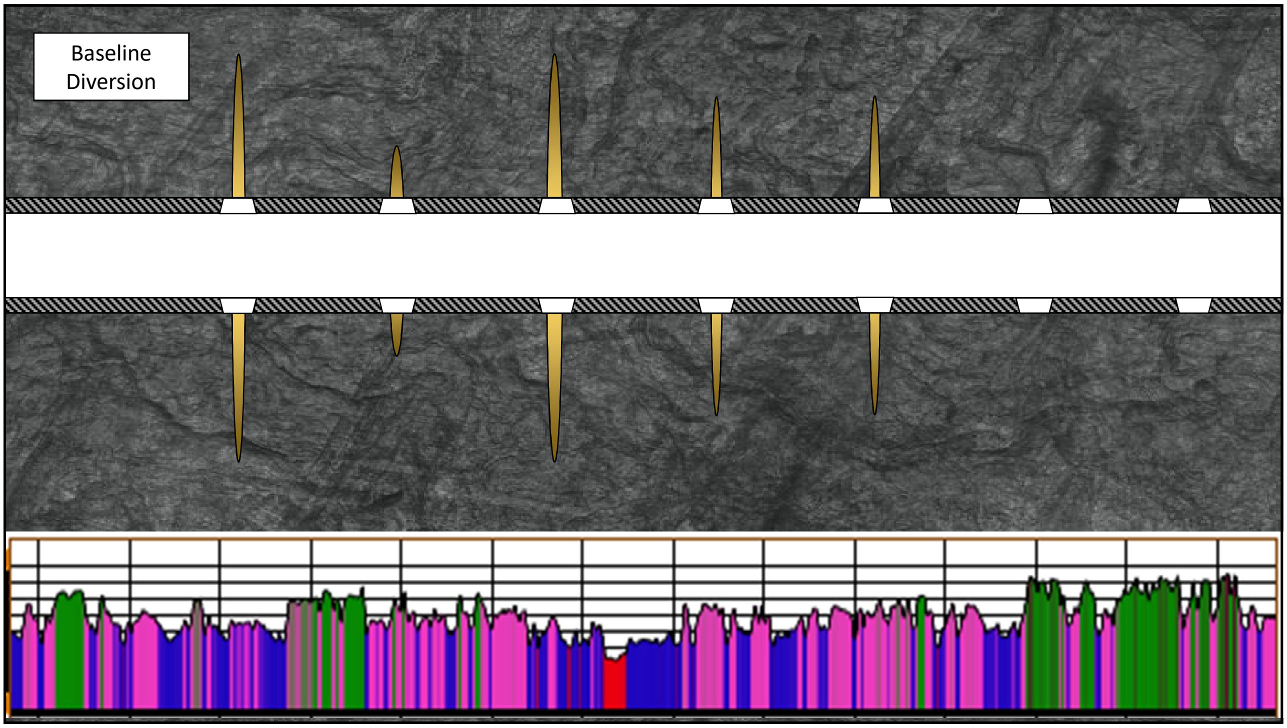
Webinars

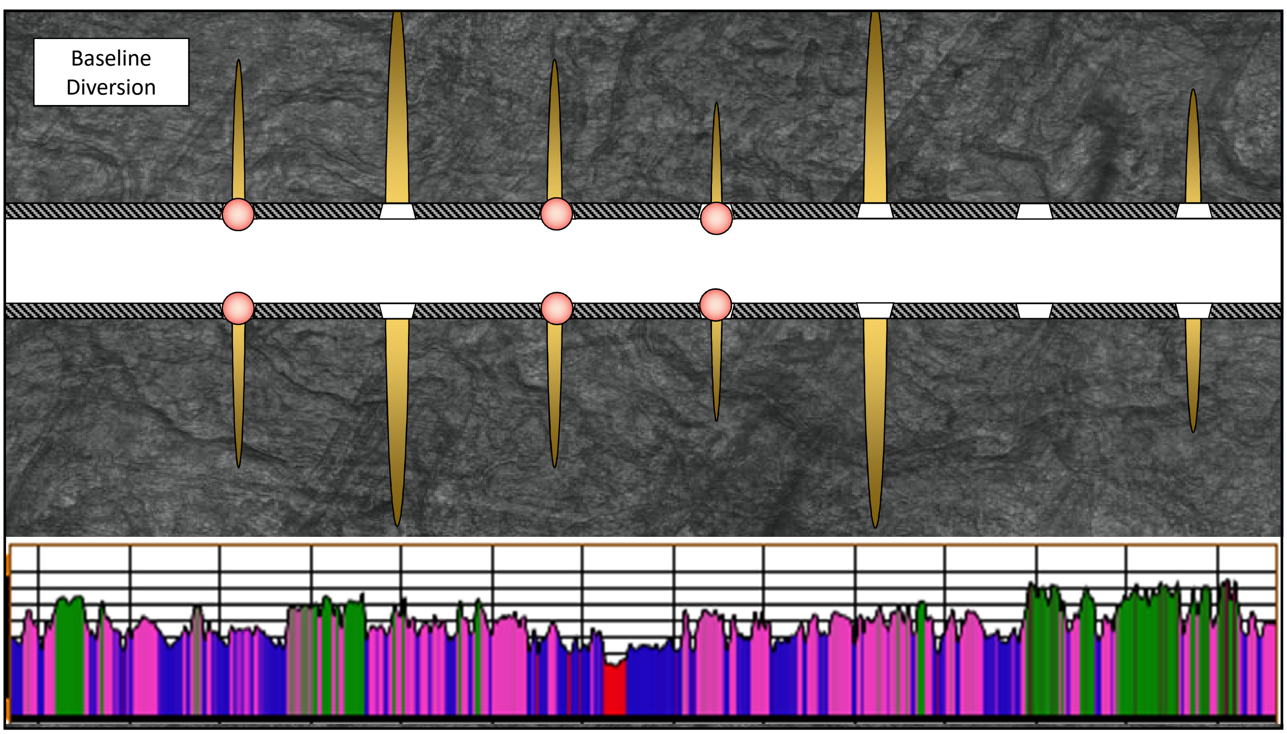
- The following animation walks through what is likely happening downhole during a fracture treatment with diverters




Baseline
Diversion


Baseline
Diversion


Baseline
Diversion


Baseline
Diversion

Design Considerations

When to Drop Diverters

- When and how much diverter should be dropped depends on how much heterogeneity you have in your stage
  - Low Heterogeneity Stage: More clusters take fluid initially, so diversion should happen later in stage, or not at all.
  - High Heterogeneity Stage: Fewer clusters take fluid initially, so diversion should happen early and possibly multiple drops

How Much Diverter to Drop

Webinars

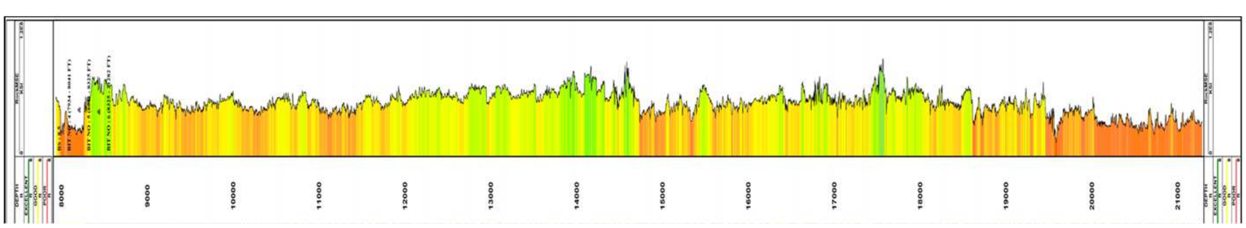
- The optimal amount of diverter to drop depends on how many fractures are accepting fluid.
  - The more fractures taking fluid the more diverter to drop

SPE International

Determining Heterogeneity

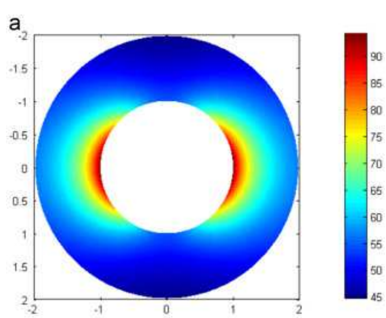
Webinars

- Need to estimate frac gradient at each perforation cluster
  - Sonic Log
  - Mechanical property proxy such as RockMSE
    - Uses data from drilling process to estimate rock hardness



Near Wellbore Effects

Perforation Phasing



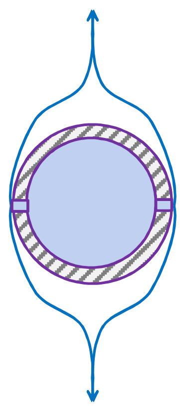
A stress cage exists in all wells as stresses distribute around a wellbore.

Perforations oriented at 90° (sides) will have a higher breakdown pressure than perforations oriented at 0° (Top and Bottom)

In standard 60° phased perforations, some perforations may never break down

Perforation Phasing

Webinars

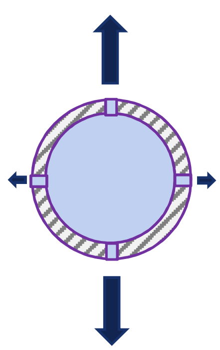


In addition, fluid entering perforations at the side of the wellbore will have greater tortuosity

SPE International

Perforation Phasing

Webinars



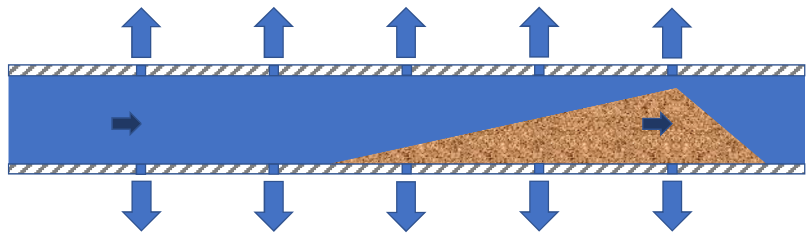
A combination of stress cage and tortuosity results in perfs at top and bottom taking more fluid that perforations at the sides.

When perforation sealers are used, it is possible that they only seal the top and bottom perforations in a cluster, opening up the perforations on the sides rather than new perforation clusters.

This would lead to higher pressures, but not effective diversion

SPE International

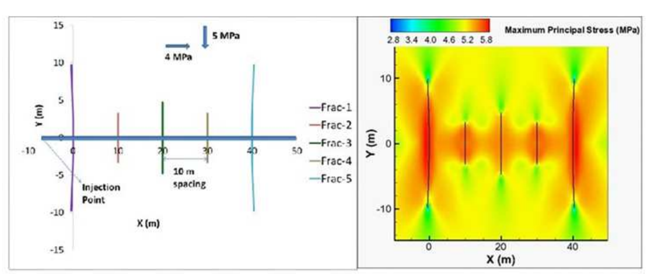
Beware of Settling Sand



In many cases, sand building up in the wellbore can cause the bottom perforations to “sand out” long before diverter hits. This can result in less diverters being needed vs number of perforations shot

Intra-Stage Stress Shadow

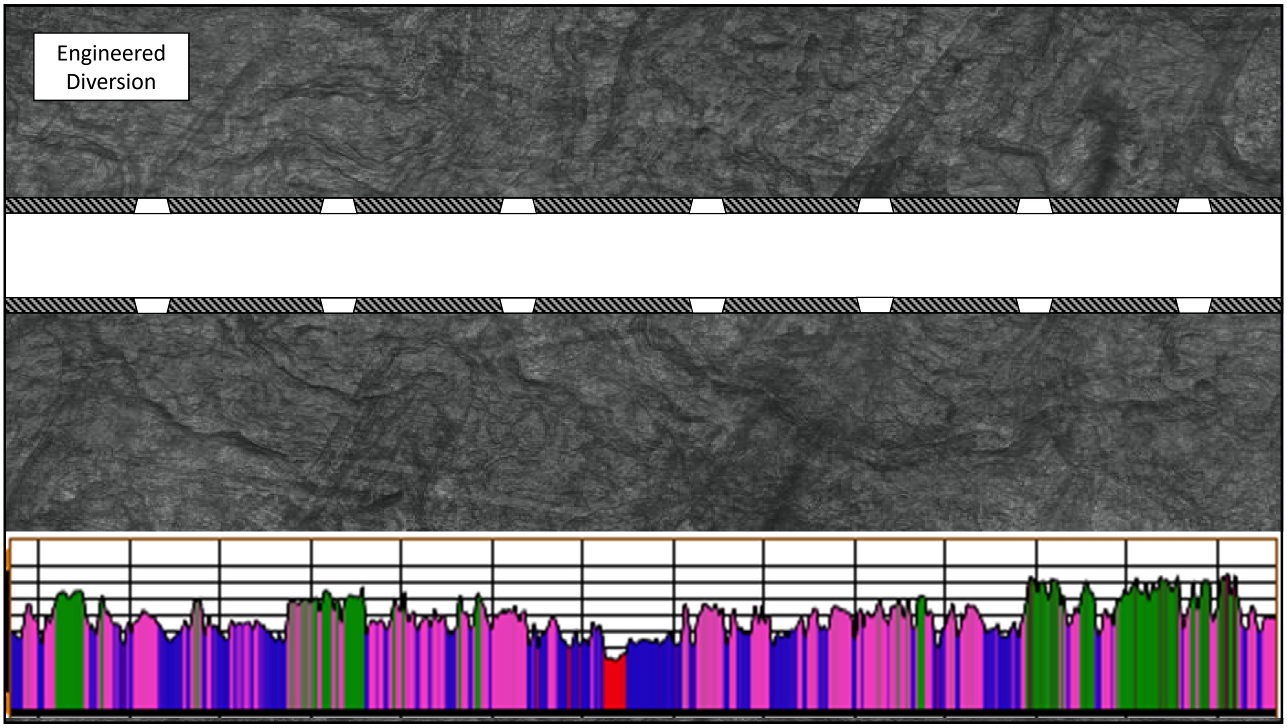
- Stress Shadows within a stage have multiple effects
  - Can pinch out fractures when too closely spaced
  - Can elevate the breakdown pressures of non-initiated clusters
  - Can effect fracture complexity

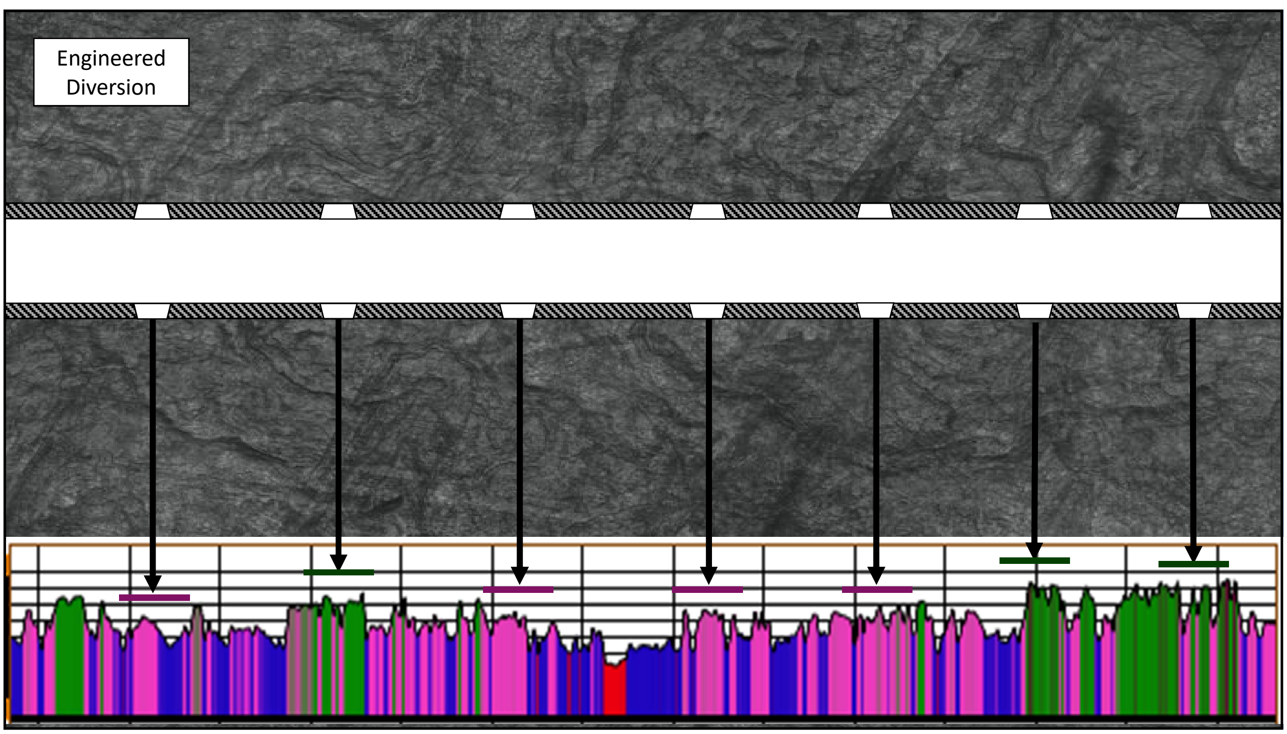


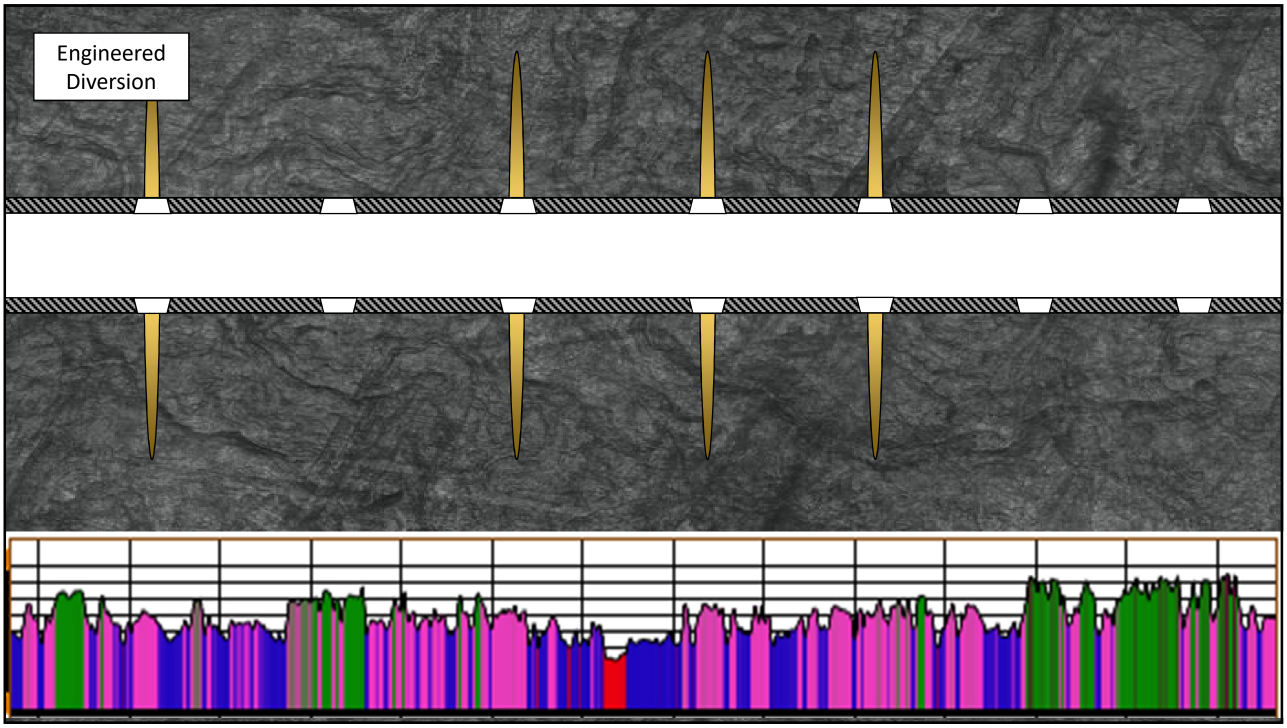
Fully Engineered Diversion

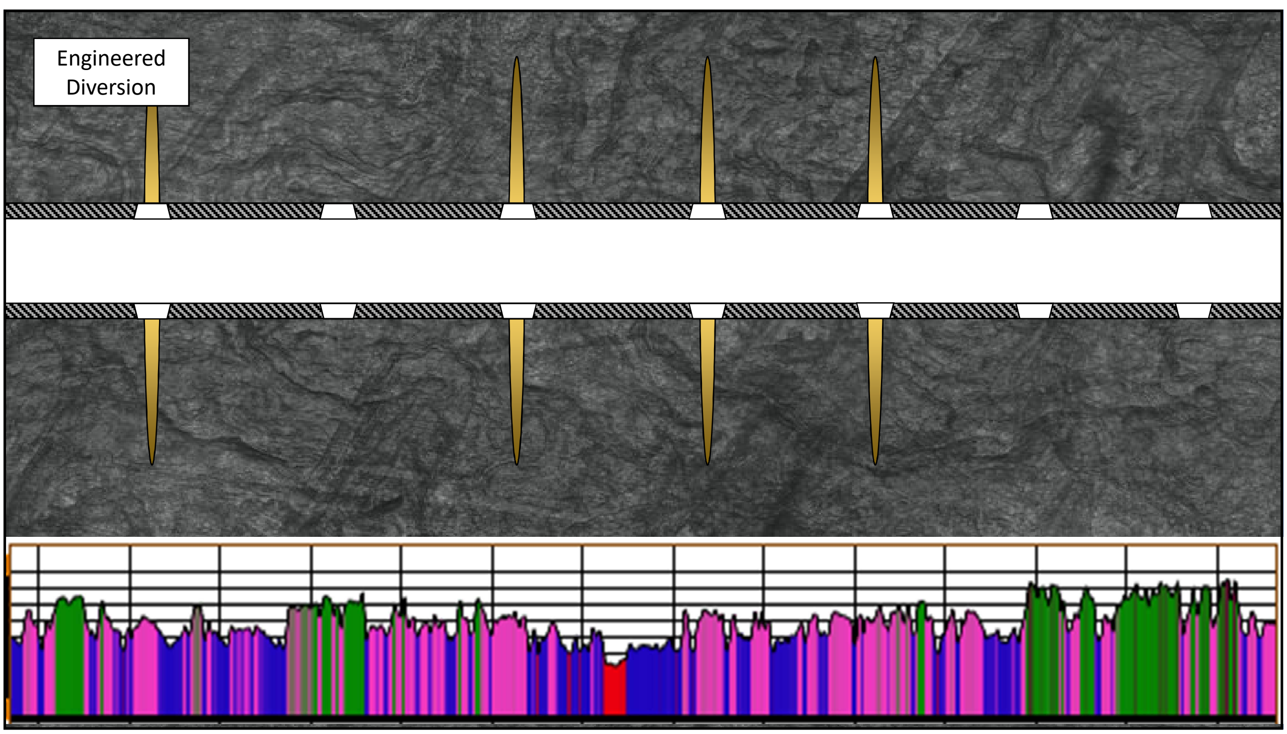
Fully Engineered Diversion

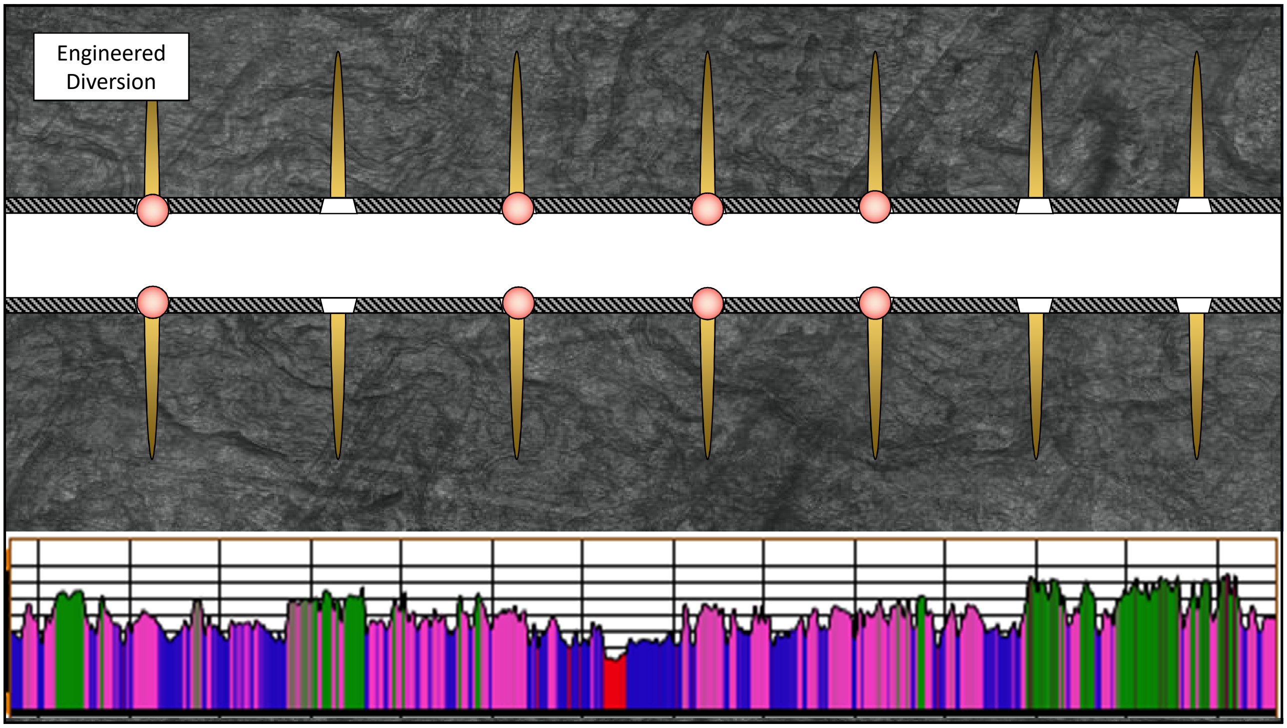
- An engineered diversion strategy uses all the concepts described previously to come up with an optimal stage specific plan
- .The following animation walks through how a fully engineered diversion solution can be applied

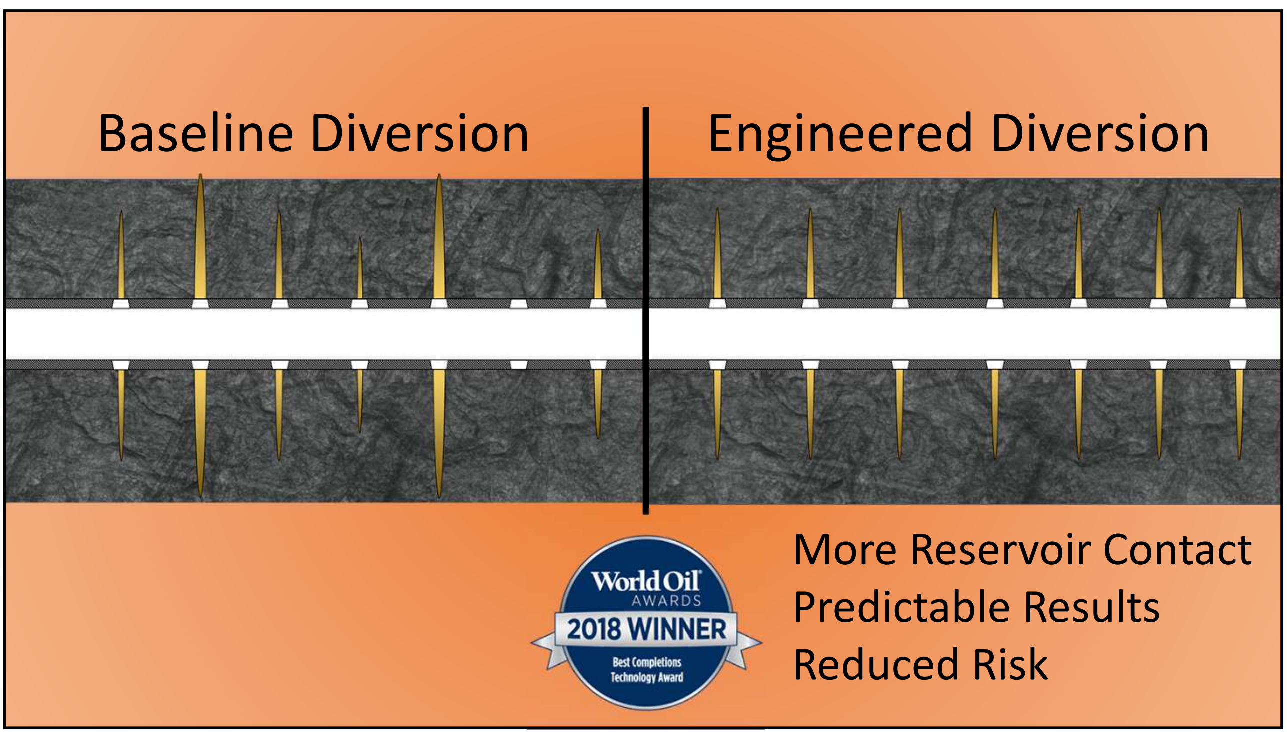

Engineered
Diversion


Engineered
Diversion


Engineered
Diversion


Engineered
Diversion


Engineered
Diversion


Baseline Diversion
Engineered Diversion
World Oil AWARDS
2018 WINNER
Best Completions Technology Award
More Reservoir Contact
Predictable Results
Reduced Risk

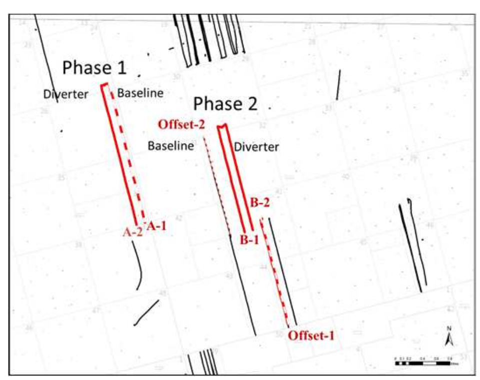
Case Study

SPE 191600

Formation: Wolfcamp

Goal: Reduce costs by increasing stage length without sacrificing production

Solution: Using perforation sealers and a fully engineered diverter design, increase stage length from 175’ to 320’



Notes:

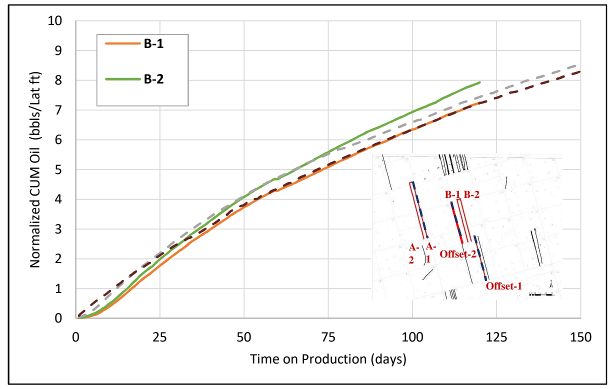
Pump schedule adjusted to keep same proppant and fluid volumes per lateral foot. Lessons learned In Phase 1 were applied to Phase 2

SPE 191600

Webinars

Results:

- Pressure response showed that 85% of drops had effective diversion
- Total completion time for phase 2 wells was 13.5% less than offset wells
- Production rate was 4% better than offsets
  - Note: Offset wells were initially unbounded



Webinars

Conclusion

Conclusions

Webinars

- Many diverter applications may be under performing due to variations in rock properties around the wellbore
- Multiple considerations must be made to design an effective diversion strategy including
  - Heterogeneity
  - Perforation phasing
  - Sand Settling
  - Stress Shadowing
- A fully and properly engineered diversion design will take all this into consideration and has shown to be an effective tool to reduce costs and improve production

SPE International

Webinars

Questions?

SPE International